

*AUTOMATIC TECHNIQUE
FOR ABSTRACTING COLOR DESCRIPTIONS
FROM AERIAL PHOTOGRAPHY*

MAY, 1967

NO. 12

by

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Technical Paper

AUTOMATIC TECHNIQUE FOR ABSTRACTING
COLOR DESCRIPTIONS FROM AERIAL PHOTOGRAPHY

To: G. A. Leonards, Director
Joint Highway Research Project

June 20, 1967

From: H. L. Michael, Associate Director
Joint Highway Research Project

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The attached Technical Paper "Automatic Technique for Abstracting Color Descriptions from Aerial Photographs" by J. Courley, H. T. Rib and R. D. Miles is submitted for approval of publication in the Proceedings of the 1967 Conference of Photographic Science and Engineering. The paper was presented by Mr. Rib on May 15, 1967.

The paper describes a simple, rapid and accurate method for selection of color descriptions on aerial photographs using transmission or reflection densitometers. A graphical method as well as a computer program were developed as a part of the research effort.

The report is presented to the Board for action on the publication request. The paper will be submitted to the Bureau of Public Roads to secure permission of publication.

Very truly yours,



Harold L. Michael

HLM:jrw

Attachment

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FROM AERIAL PHOTOGRAPHY

by

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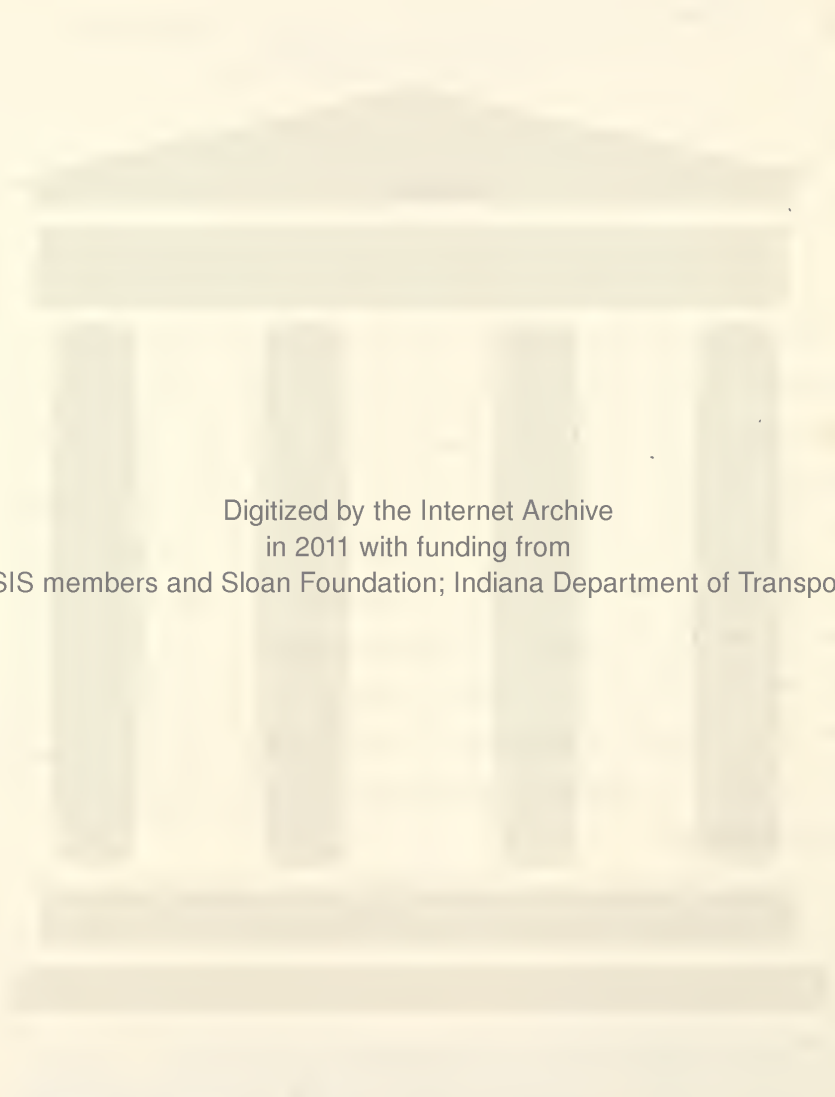
Purdue University
Lafayette, Indiana
May 11, 1967

Automatic Techniques for Abstracting Color Descriptions
from Aerial Photography
by J. Gourley, H. T. Rib, R. D. Miles*

ABSTRACT

The interpretation of color aerial photography is increasing in all disciplines of engineering and earth sciences. One of the problems facing the interpreter using color photography is the need for a rapid and automatic method of describing the various colors present on the photography which aid in the interpretation. This paper describes a simple, rapid and reasonably accurate method for automatically describing the colors present on aerial photography using simple transmission or reflection densitometers. This method describes the colors in the Munsell notation system or by descriptive names based on the ISCC-NBS system. A graphical method as well as a computer program were developed to determine the color descriptions.

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INTRODUCTION

The use of color aerial photography is increasing in various disciplines of civil engineering and the earth sciences. Color adds innumerable contrasts not detectable on the standard black-and-white aerial photography. Color is greatly increasing the amount of information that can be interpreted from the aerial photography as reported by various researchers (3) (5) (13) (14).^{1/}

The large number of contrasts available on color photography aids an interpreter in abstracting information from the photography but the colors present a problem when attempting to describe them in a qualitative sense. The use of common color names as descriptors is unsatisfactory as has been demonstrated by Chapanis (1). He has shown that there is variability among various observers as to their impression of the appearance of the common colors. In order to properly describe the color tones on the photograph, the interpreter has to provide samples of the colors described or else relate them to some readily available standard color system.

An additional factor of importance is the need to reduce the data present on photography for analysis and manipulation by computers. This feature requires a technique for color description that is simple, rapid and automatic in addition to the previous need for reference to a standard color system.

^{1/}

Number in parenthesis refers to references listed at end of paper.

Standard color measurement systems such as the Munsell system (10) and the CIE ^{2/} chromaticity method (2) (6) have been used to describe color tones present on color aerial photography. Heller et al. (5) has reported on the use of the Munsell system while Keegan et al. (6) (7) and Wenderoth and Yost (15) have reported on the use of the chromaticity method. Although these are standard systems and have been used to describe colors on color aerial photography, they do not meet the desired requirements for a simple, rapid and automatic system for color description.

The Munsell system is a simple, inexpensive system which utilizes a color matching technique. An observer matches the color of the unknown sample to standard color chips (over 1,000 standard color chips-matte finish; over 1450 standard color chips-glossy finish). The Munsell system is based on a three dimensional concept of the color solid where each chip is described in terms of three variables-hue, value and chroma. The main limitations of this system are (1) it is not amenable to automation since a person is required to do the color matching, and (2) fairly stringent illumination conditions are necessary for accurate color matching which are not normally encountered, especially in viewing color transparencies.

The CIE chromaticity system defines the color in terms of tri-stimulus points on the chromaticity diagram or by their characteristics of luminance, dominant wavelength and purity (based on a standard light source). These characteristics are usually determined by measurements of the unknown sample with a spectrophotometer and subsequent conversion

^{2/}

CIE-initials for Commission Internationale de l'Eclairage

by standard calculations to tristimulus values. The CIE system offers a method which can provide automatic evaluation of the tristimulus values; however, it is limited by several factors. These include (1) it is not a simple, rapid method and requires the use of expensive equipment, and (2) the characteristics described by this system give no direct reference to a color system which can be referred to in order to determine the appearance of the color. The CIE system has been correlated with the Munsell system so that the variables of hue, value and chroma can be determined from the stimulus values of a given sample. This factor negates to some degree this latter limitation; however, this adds to the complexity of using this system.

A third, purely descriptive system was developed by the Inter-Society Color Council and the National Bureau of Standards (ISCC-NBS system) (9). This system contains 267 descriptive color names which are arrived at by first determining the Munsell attributes-hue, value and chroma. This system has the same limitations as the Munsell system with the added disadvantage of limiting the number of colors that can be described.

The standard color measuring techniques available did not meet the specifications of a recent research project concerned with mapping soils using color ^{aerial} photography. Therefore, a system was developed as a part of the research which would give the required results. The description of this system and its application are the subjects of this paper.

DENSITOMETRIC-MUNSELL SYSTEM

The system developed is based on the Munsell system but includes measurements with densitometers instead of color matching techniques. The equipment used is relatively inexpensive. The data is collected rapidly

and is in a form which is amenable to handling with digital computers.

Equipment

The equipment and accessories utilized in the system are shown in Figure 1. The reflection densitometer (items 1a and 1b, Figure 1) was used to obtain density readings from color prints and the transmission densitometer (item 3a, Figure 1) was used to obtain density readings from color transparencies and negatives. Both densitometers are point measuring instruments and each contain four filters. The filters included in the reflection densitometer are Wrattens 106W (visual), 25 (red), 47 (blue) and 58 (green). The filters included in the transmission densitometer are Wrattens 106W (visual), 92 (red), 93 (green) and 94 (blue). The other equipment shown in Figure 1 are accessories used in the operation or calibration of the system. The chart recorder unit (item 2a) can be used to automatically record the density readings obtained for all filters on either densitometer. The voltage divider unit (item 2b) is used to balance the output of the densitometers to the recorder input and also provides a switch for selection of the densitometer.

Technique

The technique for the determination of the three attributes of the Munsell system-hue, value and chroma was developed by taking reflection densitometer readings for every chip within the Munsell Book of Color (matte finish) (10). Each piece of data consisted of a set of density readings obtained through four filters (visual, red, green, blue). These readings supplied the basic data which, upon manipulation, gave rise to



1 COMPONENTS OF REFLECTION DENSITOMETER

1a.- REFLECTION DENSITOMETER CONTROLS & METER

1b.- MEASURING PROBE AND FILTER SELECTOR

1c.- 30 VA SOLA VOLTAGE REGULATOR

1d.- 10 STEP CALIBRATED REFLECTION PLAQUE

2 COMPONENTS OF CHART RECORDER

2a.- CHART RECORDER

2b.- VOLTAGE DIVIDER UNIT

3. COMPONENTS OF TRANSMISSION DENSITOMETER

3a.- TRANSMISSION DENSITOMETER

3b.- 60 VA SOLA VOLTAGE REGULATOR

3c.- 20 STEP CALIBRATED TRANSMISSION TABLET 0-4.0 DENSITY

FIGURE 1. EQUIPMENT USED FOR QUANTITATIVE ANALYSIS.

the system discussed. After visual inspection and trial and error techniques, basic concepts were developed for the classification system. Six random samples were taken from each page, making 240 random samples in all. These readings were used as basic data for the development of a computer program and later for the refinement of the system.

Hue: The element of the Munsell notation requiring the most elaborate procedure is that of hue. The procedure developed is dependent on the use of the red, green and blue density readings only. The spectrum may be divided into three zones, those of red, green and blue dominance. By means of the density readings, the dominant zone can be selected. These zones may be further divided into two parts by use of the minor color. Thus on the basis of a simple test for maximum and minimum effects the spectrum can be divided into six parts by the use of three primary colors.

Steps 1 and 2 in the determination of hue involve a simple inspection of the density values to determine the filter color of the largest and the smallest reading. These steps narrow the spectrum down to one of the six regions.

Steps 3, 4, and 5 involve a technique for selecting the relevant spectral range of a sample. This technique is dependent on evaluating the relative size of the largest reading with regard to each of the remaining two readings. In order to do this, two differences are computed:

- a. The largest reading minus the intermediate reading,
- b. The intermediate reading minus the smallest reading.

On the assumption that there will be a gradual shift in relative emphasis across the spectrum these two differences present a definitive tool, which when applied to the basic six zones, enables hue to be estimated

within reasonable limits. In the case when the three color density readings are almost the same there is no 'color' and the hue is thus neutral.

The chart developed to obtain hue is shown in Figure 2. The abscissa refers to the page numbers in the Munsell Book of Color, (1929 edition). Each block represents a 2.5 step in hue. Thus the number of the first page is 2.5, the second 5.0 and the fortieth is 100. The series of steps indicated vertically represent successive stages in the narrowing of the spectral ranges until the final relevant hue range is obtained. The use of this chart will be demonstrated subsequently by a series of examples.

Value: The Munsell value notation was clearly related to the visual density reading. The empirical relationship $V = 15 - 2.5$

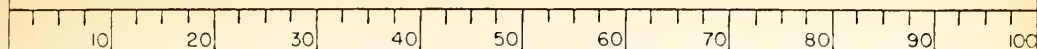
~~3~~ visual density reading was found to give good results for the data processed. A plot of the formula is shown in Figure 3 as curve 1.

An alternative method was also developed which used the intermediate reading from the red, green and blue readings and this performed nearly as well.

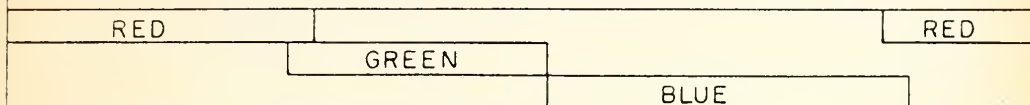
Chroma: A reliable method of chroma determination proved to be a little elusive in the first instance. The principal tool which was investigated as a definitive parameter was the ratio formed by dividing the difference between the greatest and the smallest of the three color density readings by the smallest density reading. It became apparent that the value notation also had to be considered and the combination of these two parameters lead to a satisfactory results.

The curves used for determining Value and Chroma are shown in Figure 3.

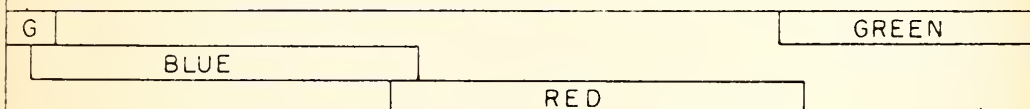
MUNSELL PAGES



1. LOWEST COLOR DENSITY DETERMINES RANGE



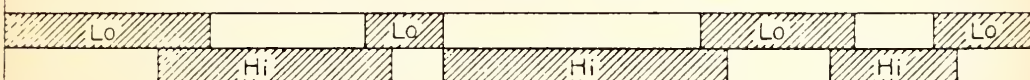
2. HIGHEST COLOR DENSITY DETERMINES RANGE



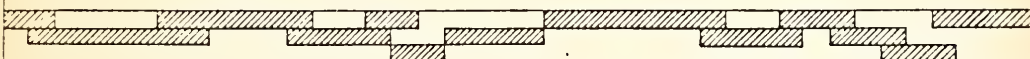
3. ENTER WITH LARGEST "Hi" or "Lo"

"Hi" = largest density reading - intermediate density reading

"Lo" = intermediate density reading - smallest density reading



4. SELECT RANGE SATISFYING THREE CRITERIA



5. ENTER SELECTED RANGE WITH RR

$RR = "Hi"/"Lo"$ or vice versa ($RR > 1$)

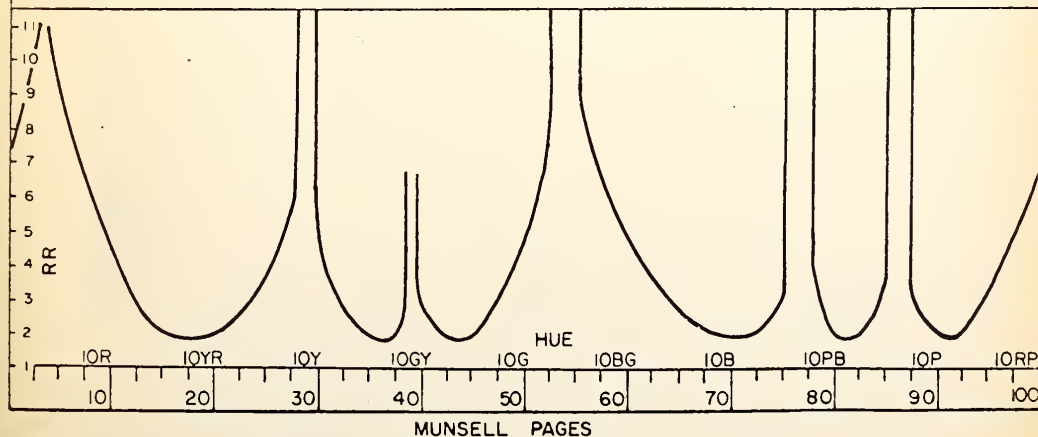


FIGURE 2. TECHNIQUE FOR SELECTION OF HUE.

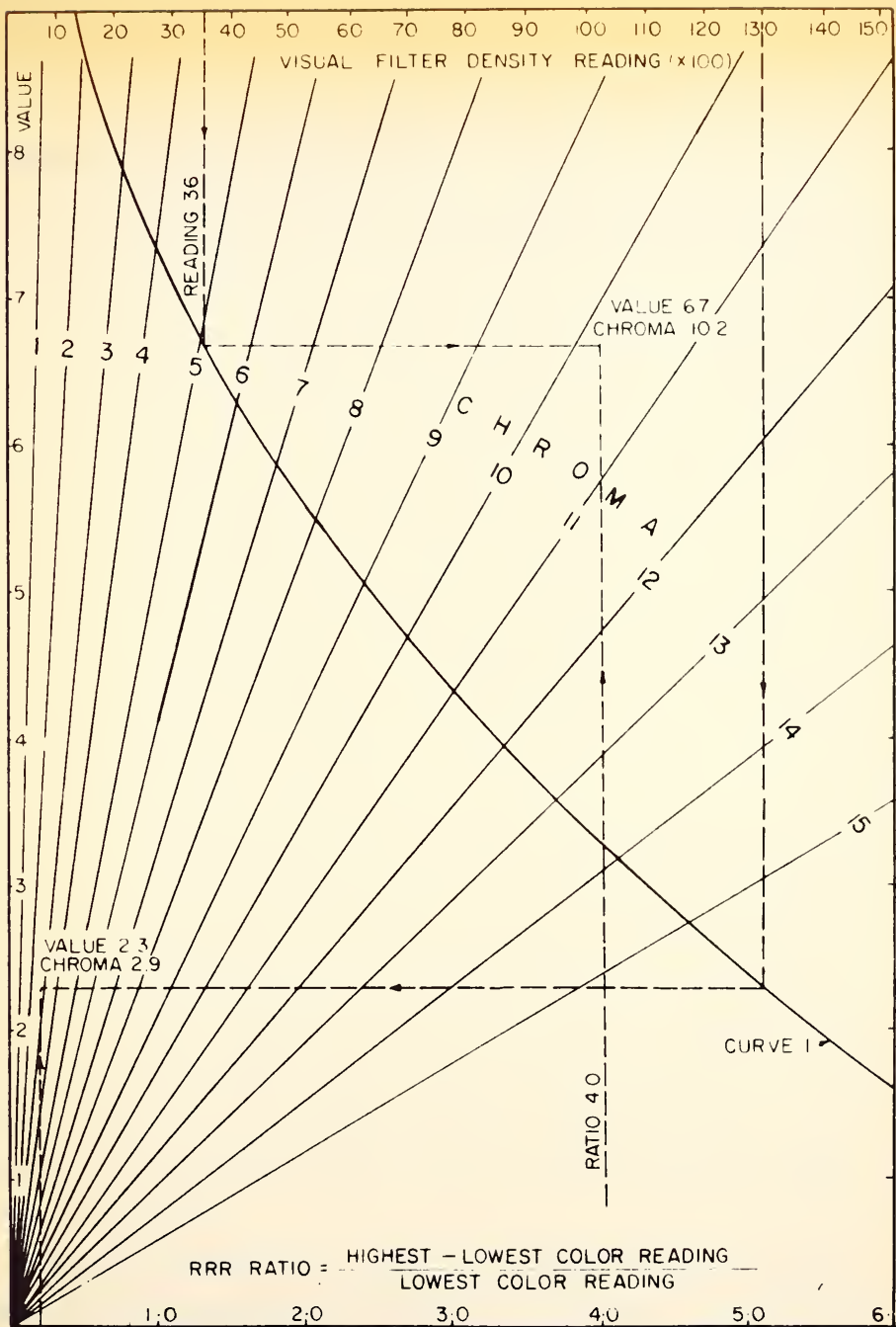


FIGURE 3. TECHNIQUE FOR ASSIGNING
VALUE AND CHROMA

Explanation of the Use of the Graphs

For each color sample, four density readings are taken through visual, red, green and blue filters.

Hue (Figure 2): - Using only the red, green and blue readings, the filter which gives the highest density reading and the filter which gives the lowest, are determined. The actual amount of the reading is not important. This information, applied to steps 1 and 2 of Figure 2, determines which of the six hue zones applies in this case.

Then, the difference between the highest reading and the middle reading, and between the middle reading and the smallest reading are taken. If the first difference is larger than the second, one of three shaded zones marked "Hi" must apply, otherwise the sample lies in one of four marked "Lo."

The three pieces of information determined above enables one to select one of 12 ranges as shown in step 4 on the figure. These spectral ranges are seen to vary from relatively narrow ones to relatively wide ones and it is desirable to be able to reduce the answer to a reasonably narrow range. This is accomplished in the final step 5 by a graph for the ratio, RR (ratio between the two differences used in step 3). This ratio is always that of the greatest difference over the smallest. The purpose of this operation is merely to narrow down the preselected range, where this is possible.

Value and Chroma (Figure 3) :-Value is determined first. The chart is entered at the top with the visual density reading and a vertical line extended until it intersects curve 1. A horizontal line projected from this point to the left hand-vertical scale gives the appropriate value

notation. The chroma is then determined. The chart is entered along the bottom abscissa at the calculated RRR ratio. A vertical line is projected upward until it intersects the horizontal line representing the "Value" previously determined. The point of intersection of these two lines, as related to the diagonal lines radiating from the origin, determines the chroma.

Typical Examples

Three examples are included to demonstrate the use of the charts (Figures 2 and 3). Although with the use of these charts, value and chroma can be estimated to the nearest tenth of a unit, the results are shown to the closest Munsell chip in the Munsell Book of Color. Attempts to estimate these properties any closer is beyond the accuracy or intent of this system. The corresponding ISCC-NBS color description is also included.

For ease of calculations, all density values were multiplied by 100 to eliminate decimals.

EXAMPLE 1. - density readings (x 100)

Red	20
Green	40
Blue	100
Visual	36

Hue: Using Red, Green and Blue density readings and Figure 2.

1. Red is smallest-range is 0 to 30 and 87.5 to 100
(0 and 100 correspond)
 2. Blue is highest-range is 5 to 40
- Overlap zone from 1 and 2 gives a range from 5 to 30
inclusive

3. The intermediate color is green

$$\text{"Hi"} = \text{Blue} - \text{Green} = 100 - 40 = 60$$

$$\text{"Lo"} = \text{Green} - \text{Red} = 40 - 20 = 20$$

"Hi" greater than "Lo"; therefore, the "Hi" zone lying within the above region applies (i. e.

17.5 to 37.5)

4. Overlap zone from steps 1, 2, and 3 is now narrowed down to 17.5 to 30 inclusive as is indicated in step 4 on the chart.
5. Ratio of differences $RR = 60/20 = 3$ (see step 3). Projecting a horizontal line from $RR = 3$ into the range 17.5 to 30 on the graph, results in an intersection at Munsell page 25.

Hence the Munsell page is 25 or hue is 5Y.

Value and Chroma: Using all four readings and Figure 3.

Enter top scale with visual reading = 36

Read value corresponding to intersection with curve 1., = 6.7

$$\text{Calculate RRR} = \frac{100 - 20}{20} = 4.0$$

Find the intersection of the vertical line drawn from 4.0 on the bottom scale with the horizontal drawn from value 6.7.

This point lies in the chroma band 10 to 11, estimated position 10.2.

The full Munsell notation - Hue Value/Chroma (to nearest chip in Munsell Book of Color) is 5Y 7/10. Corresponding ISCC-NBS color is strong yellow.

EXAMPLE 2. - density readings (x 100)

Red	135
Green	120
Blue	144
Visual	130

Hue: Using Red, Green and Blue density readings and Figure 2.

1. Green is smallest-range is 30 to 52.5

2. Blue is highest-range is 5 to 40

Overlap zone from 1 and 2 narrows the range to 30 to 40
inclusive

3. The intermediate color is red

$$\text{"Hi"} = \text{Blue-Red} = 144-135 = 9$$

$$\text{"Lo"} = \text{Red-Green} = 135-120 = 15$$

"Lo" greater than "Hi"; therefore, the "Lo" zone

lying within the above region applies (i. e. 37.5-
42.5)

4. Overlap zone from steps 1, 2 and 3 is now narrowed down
to 37.5 to 40 inclusive as is indicated in step 4 on the
chart.

5. Ratio of difference $RR = 15/9 = 1.7$

This ratio plots below the graph and is therefore taken
as 2 in order to obtain the hue. This corresponds to a

Munsell page of 37.5 or hue of 7.5 GY.

Value and Chroma: Using all four readings and Figure 3.

Enter top scale with visual reading = 130

Read value corresponding to intersection with curve 1., = 2.3

$$\text{Calculate RRR} = \frac{144-120}{120} = 0.2$$

Find the intersection of the vertical line drawn from 0.2 on the bottom scale with the horizontal line drawn at "Value" of 2.3. This point lies in the chroma band 2-3, estimated position 2.9. The full Munsell notation- Hue, Value/Chroma (to nearest Munsell chip) is 7.5 GY 2/2.3/ Corresponding ISCC - NBS color is dark grayish olive green.

EXAMPLE 3. - density readings (x 100)

Red	107
Green	108
Blue	107
Visual	108

Hue: Since difference between density readings for three color filters is less than 3, the hue is neutral.

Value: From Figure 3, enter top scale with visual reading = 108.

Read value corresponding to intersection with curve 1, = 2.9.

Munsell notation is N 3/. Corresponding ISCC-NBS color is dark gray.

General Comments on Graph

In Figure 2 it is noted that the RR graph has regions which are unbounded. This is to accommodate large values of RR which occur when two of the colors have the same density reading or nearly so. This can result in a division by a very small number in the calculation of RR.

3/

Chroma chips in 1929 Munsell Book of Color only present in steps of two.

In those cases where RR is less than 2 and the horizontal projection of RR does not intersect the graph, any location with the limits set by the $RR = 2$ intersection would be possible, i.e., beneath the trough of the curve.

An additional item noted is that the widths in the principal zones are unequal and these result in unequal subdivisions in further steps. This system was based on the filters present in the Macbeth reflection densitometer. The unequal width of the principal zones could no doubt be eliminated by careful selection of the red, green and blue filters. This would probably increase the accuracy obtained in hue prediction. Further studies in this area are presently underway.

Discussion of System

The technique of determining the Munsell notation demonstrated in this paper is a graphical method. A computer program has been developed to determine the Munsell notation. The program was drafted in MAD language for handling by Purdue's IBM 7094. The program is available on file at the Department of Civil Engineering, Purdue University.

If a descriptive color name is desired in lieu of a Munsell notation, the ISCC-NBS method of designating colors can be utilized. This system however, is limited in the number of colors that can be described to 267 compared to over one thousand standard color chips in the Munsell system.

EVALUATION OF PERFORMANCE

Prediction Performance

To check the accuracy of prediction of Munsell notations by this system, checks were made between the Munsell notation developed by this method and the actual Munsell notations. Three different sets of data were compared. These included: (1) the original 240 matte samples on which the system was developed; (2) 250 glossy samples in the ISCC-NBS Centroid Color Charts (8); and (3) readings taken on additional chips from a second Munsell Book of Color. Accuracies obtained were:

Hue-85 to 95 per cent within ± 1 Munsell step (one page of book)

99 per cent within ± 2 Munsell steps

Value-99+ per cent within ± 1 value step

Chroma-98 per cent within ± 1 unit of chroma (chroma goes in steps of 2, e.g., 2, 4, 6, 8,).

The average error in a three dimensional sense, assuming units of hue, value and chroma are equivalent, was 1.4 units. This would indicate that in the attempt to pick the exact chip, two of the three components would be one unit away, and the third one would be correct.

Comparison of Accuracies

Comparison of the accuracy of this rather simple system to results reported in the literature for the more sophisticated systems indicates the accuracy of this method is not significantly different than these systems. Godlove and Munsell (4) reported that the disagreement between the direct color matching method and indirect methods (spectrophotometry

and transformation by computation to hue and chroma) indicated the determination of the indirect method was about equal to the uncertainty of the direct method which had an average uncertainty of one Munsell hue step and one-half Munsell chroma step. Nickerson et al., (11) indicated that the average difference between renotations based on visual observations and renotations based on spectrophotometric methods for some 76 samples was hue 1.2 ± 1.0 ; value 0.2 ± 0.3 and chroma 0.6 ± 0.2 .

These results indicate that at least for determining Munsell notation, the system developed had about the same degree of accuracy as other indirect measuring methods. This method however, had the added advantage that it was simpler, faster and the equipment was less expensive.

APPLICATION TO MEASUREMENTS ON COLOR PHOTOGRAPHY

Prints vs. Positive Transparencies

The system developed was based on measurements with the reflection densitometer on positive matte or glossy surfaces. However, most of the color photography obtained are transparencies, and the density measurements can only be made with the transmission densitometer. To check if the system was equally applicable to measurements with a transmission densitometer on transparencies, selected spots were measured on both transparencies and positive color prints made from the transparencies. Care was taken to select areas that had uniform color tones and that the same point was read on both types.

Results of these comparisons indicated that transmission readings taken on transparencies can be used to predict a color notation for an object as it would appear on a print. However, hue prediction is not

as consistent in regions of very light or very dark ranges of value and chroma due to variabilities of reproduction. Value and chroma can be predicted fairly well. Value notation corrections to be applied to transparency results are dependent directly on the value obtained on the transparencies. The following listing indicates the adjustments needed on two different film types for converting the Munsell attributes on the transparencies to those of the prints.

transparency

conversion to print

EKTACHROME

hue
value
chroma

use directly
multiply value by two
use directly

EKTACHROME-~~INFRARED~~

hue
value
chroma

use directly
multiply by 1.5
multiply by 1.5 then
subtract 5; when
transmission chroma
 ≤ 3 , chroma on print
is zero.

The results indicated above are based on preliminary comparisons. The variabilities present in the developing and printing of color prints required the judicious choice of points for comparisons. Further study is underway on this aspect of the system.

Negatives vs. Prints

Limited comparisons were also made to determine if Munsell notations could be predicted for positive prints based on measurements of color negatives. Several trends were noted, for example, on Kodak Aero-Negative

color, the difference was 20 hue steps (complimentary colors), while for Agfa negative color, the difference was about 10 hue steps. These results are inconclusive however, as it does not represent a large sample.

Preparation of Isochromal Maps

Preliminary attempts were made to prepare isochromal maps (maps showing uniform color regions) from color aerial photography. Maps were prepared from point density readings taken with four filters on a one-half inch grid system. An isochromal trace was also prepared by scanning successively with the four filters along one continuous scan line. The color zones on the maps were determined by utilizing the system developed for determining Munsell hue. These trial maps were then visually compared to the original color tones present on the phtography. Zones were noted where colors were comparable between the isochromal map and the original photograph.

This technique is still in the initial stages of development. The correlations made to date indicate that this method does provide a means of automatic extraction of raw color data from aerial photography. The potentials for this technique appear great for automatically extracting areas of particular colors which may be related to terrain conditions of interest on the photography.

SUMMARY AND CONCLUSIONS

A rapid, and simple system was developed for determining Munsell color notations or ISCC-NBS descriptive color names. The technique is based on measuring the sample point with a densitometer. Four readings

are taken per sample point using four filters (visual, red, green, and blue) and by using the graphs developed, the Munsell notation is determined. The accuracy of the system for the intended purpose is comparable in accuracy to other more elaborate indirect measuring methods.

This system can be utilized to describe colors on both positive color prints and positive color transparencies. It was noted that corresponding colors could be obtained on both film types. Measurements of color negatives and positives indicated the possibilities of predicting the final color on the positive print from measurements on the color negatives. The technique developed can be used to prepare isochromal maps from color photography. The use of isochromal mapping techniques has great potential for delineating various terrain conditions of interest based on particular color tonal patterns present on aerial photography.

The system described in this paper provides a simple and rapid solution to the interpreter's problem of naming the various color tones present on color aerial photography. It also provides a technique for reducing the raw color data to a form that can be handled by computers. There are certainly areas where this technique can be improved and studies are presently underway to accomplish this. However, the main question at this stage is not how many colors can be discriminated or the accuracy in naming them, but how many, or which colors present on the photography are unique or indicative of the features of interest. This is the area where further research is needed. The ability to reduce the data for handling by computers should greatly facilitate this research effort.

ACKNOWLEDGEMENTS

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REFERENCES

1. Chapanis, A., "Color Names for Color Space," American Scientist, pp. 327-346, September 1965.
2. Committee on Colorimetry, Optical Society of America, The Science of Color, New York, Thomas Y. Crowell Company, 1953.
3. Fischer, W. A., "Color Aerial Photography in Geologic Investigations," Photogrammetric Engineering, Vol. XXVIII, (1), pp. 133-139, March, 1962.
4. Godlove, J. H., Munsell, A. E. O., "Colorimetry With Reflection Standards: A Quasi-Psychological Method-Interconversion of Physical and Psychological Color Specifications," Journal of the Optical Society of America, Vol. 24, pp. 267-271, October, 1954.
5. Heller, R. C., Doverspike, G. E., Aldrich, R. C., "Identification of Tree Species on Large Scale Panchromatic and Color Aerial Photographs," U. S. Department of Agriculture, Forest Service, Agricultural Handbook, No. 261, July, 1964.
6. Judd, D. B., Color in Business, Science and Industry, New York, John Wiley and Sons Inc., 1952.
7. Keegan, H. J., Schleter, J. C., Haas, G. M., Hall, W. A. Jr., "Spectrophotometric and Colorimetric Study of Color Transparencies of Some Natural Objects," National Bureau of Standards Report, No. 4794, March, 1957.
8. Keegan, H. J., Schleter, J. C., Haas, G. M., Hall, W. A., Jr., "Spectrophotometric and Colorimetric Study of Color Transparencies of Some Man-made Objects," National Bureau of Standards Report, No. 4953, November, 1957.
9. Kelly, K. L., Judd, D. B., "The ISCC-NBS Method of Designating Colors and a Dictionary of Color Names," National Bureau of Standards, Circular 553, 1955.
10. Munsell Book of Color, Baltimore, Munsell Color Company Inc., 1929.
11. Nickerson, D., Kelly, K. C., Stultz, K. F., "Color of Soils," Journal of the Optical Society of America, Vol. 35, (4), pp. 297-300, April, 1945.
12. Pierce, W. O'D., "Individual Differences in Normal Colour Vision," British Medical Research Council, 1933.
13. Rib. H. T., "An Optimum Multisensor Approach for Detailed Engineering Soils Mapping," PhD Dissertation, Purdue University, January, 1967.

14. Strandberg, C. H., "Water Quality Analysis," Photogrammetric Engineering, Vol. XXII, (2), pp. 234-248, March, 1966.
15. Wenderoth, S., Yost, E., Jr., "A Rapid Access Color Reconnaissance System," presented at the Society of Photo-Optical Instrumentation Engineers Seminar-In-Depth, April 25-26, 1966.

